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INTERNATIONAL PRELIMINARY EXAMINATION REPORT

(PCT Article 36 and Rule 70)

Applicant's or agent's file reference XA1531	**FOR FURTHER ACTION**	See Notification of Transmittal of International Preliminary Examination Report (Form PCT/IPEA/416)
International application No. PCT/GB 03/01672	International filing date *(day/month/year)* 17.04.2003	Priority date *(day/month/year)* 22.04.2002
International Patent Classification (IPC) or both national classification and IPC G01S17/58		
Applicant BAE SYSTEMS PLC et al.		

1. This international preliminary examination report has been prepared by this International Preliminary Examining Authority and is transmitted to the applicant according to Article 36.

2. This REPORT consists of a total of 11 sheets, including this cover sheet.

   ☒ This report is also accompanied by ANNEXES, i.e. sheets of the description, claims and/or drawings which have been amended and are the basis for this report and/or sheets containing rectifications made before this Authority (see Rule 70.16 and Section 607 of the Administrative Instructions under the PCT).

   These annexes consist of a total of 5 sheets.

3. This report contains indications relating to the following items:

   - I ☒ Basis of the opinion
   - II ☐ Priority
   - III ☐ Non-establishment of opinion with regard to novelty, inventive step and industrial applicability
   - IV ☒ Lack of unity of invention
   - V ☒ Reasoned statement under Rule 66.2(a)(ii) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement
   - VI ☐ Certain documents cited
   - VII ☐ Certain defects in the international application
   - VIII ☐ Certain observations on the international application

Date of submission of the demand	Date of completion of this report
14.11.2003	26.07.2004
Name and mailing address of the international preliminary examining authority: European Patent Office D-80298 Munich Tel. +49 89 2399 - 0 Tx: 523656 epmu d Fax: +49 89 2399 - 4465	Authorized Officer Hekmat, T Telephone No. +49 89 2399-7132

INTERNATIONAL PRELIMINARY EXAMINATION REPORT

International application No. PCT/GB 03/01672

I. Basis of the report

1. With regard to the **elements** of the international application *(Replacement sheets which have been furnished to the receiving Office in response to an invitation under Article 14 are referred to in this report as "originally filed" and are not annexed to this report since they do not contain amendments (Rules 70.16 and 70.17))*:

Description, Pages

1, 4-10	as originally filed
2-3	received on 01.07.2004 with letter of 01.07.2004

Claims, Numbers

1-13	received on 01.07.2004 with letter of 01.07.2004

Drawings, Sheets

1/2-2/2	as originally filed

2. With regard to the **language**, all the elements marked above were available or furnished to this Authority in the language in which the international application was filed, unless otherwise indicated under this item.

   These elements were available or furnished to this Authority in the following language: , which is:

   ☐ the language of a translation furnished for the purposes of the international search (under Rule 23.1(b)).

   ☐ the language of publication of the international application (under Rule 48.3(b)).

   ☐ the language of a translation furnished for the purposes of international preliminary examination (under Rule 55.2 and/or 55.3).

3. With regard to any **nucleotide and/or amino acid sequence** disclosed in the international application, the international preliminary examination was carried out on the basis of the sequence listing:

   ☐ contained in the international application in written form.

   ☐ filed together with the international application in computer readable form.

   ☐ furnished subsequently to this Authority in written form.

   ☐ furnished subsequently to this Authority in computer readable form.

   ☐ The statement that the subsequently furnished written sequence listing does not go beyond the disclosure in the international application as filed has been furnished.

   ☐ The statement that the information recorded in computer readable form is identical to the written sequence listing has been furnished.

4. The amendments have resulted in the cancellation of:

   ☐ the description, pages:

   ☒ the claims, Nos.: 14,15

   ☐ the drawings, sheets:

5. ☐ This report has been established as if (some of) the amendments had not been made, since they have been considered to go beyond the disclosure as filed (Rule 70.2(c)).

   (Any replacement sheet containing such amendments must be referred to under item 1 and annexed to this report.)

6. Additional observations, if necessary:

IV. Lack of unity of invention

1. In response to the invitation to restrict or pay additional fees, the applicant has:

   ☐ restricted the claims.

   ☒ paid additional fees.

   ☐ paid additional fees under protest.

   ☐ neither restricted nor paid additional fees.

2. ☐ This Authority found that the requirement of unity of invention is not complied with and chose, according to Rule 68.1, not to invite the applicant to restrict or pay additional fees.

3. This Authority considers that the requirement of unity of invention in accordance with Rules 13.1, 13.2 and 13.3 is

   ☐ complied with.

   ☒ not complied with for the following reasons:

   see separate sheet

4. Consequently, the following parts of the international application were the subject of international preliminary examination in establishing this report:

   ☒ all parts.

   ☐ the parts relating to claims Nos. .

V. Reasoned statement under Article 35(2) with regard to novelty, inventive step or industrial applicability; citations and explanations supporting such statement

1. Statement

Novelty (N)	Yes:	Claims	1-13
	No:	Claims	
Inventive step (IS)	Yes:	Claims	6-12
	No:	Claims	1-5,13
Industrial applicability (IA)	Yes:	Claims	1-13
	No:	Claims	

2. Citations and explanations

see separate sheet

The following documents are referred to in this communication:

D1: GB-A-2 265 514 (MARCONI GEC LTD) 29 Sep. 1993 cited in the application
D2: US-A-6 034 760 (REES FRANK L) 7 March 2000

Point IV:

The present application is considered to lack unity, R. 13 PCT.

In particular, the following groups of inventions can be identified:

Group 1: Claims 1-7 and 13,
a laser vibrometer having an array of coherent optical receivers for identifying remote targets by detecting mechanical vibrations, whereas the output signals of the receivers are combined **in a multiple input phase-locked loop,** in order to minimize the speckle effect,

Group 2: Claims 1 and 8-13,
a laser vibrometer having an array of coherent optical receivers for identifying remote targets by detecting mechanical vibrations, whereas the output signals of the receivers are combined **in an autocovariance processor** in order to minimize the speckle effect.

Both invention groups are based on the independent claim 1 defining:

A laser vibrometer for identifying remote targets by detecting mechanical vibrations therein, the vibrometer having an array of coherent optical receivers for collecting a portion of laser light reflected by a remote targe, each receiver providing a coherent output, and signal processor means for combining the coherent outputs of the receivers to produce a signal representative of the remote target and for removing laser speckle.

However, the combination of documents D1 and D2 renders all features of claim 1 obvious (see point V, below). Thus, the subject-matter of claim 1 is considered to lack inventive step.

Therefore, the dependent claims 2-12 (independent claim 13 is defining the

corresponding method of claim 1) unravel in the two above groups reflecting two different inventions, in which the dependent claims 2-7 define a **multiple input phase-locked loop** and dependent claims 8-12 define an **autocovariance processor.** Whereas, in each case a completely different approach is used for combining signals in order to minimize the laser speckle (non-inventive feature of claim 1) and accordingly, the two invention groups do not comprise any common special technical features, R. 13.2 PCT. Consequently, the two groups of inventions are not so linked to form a single general inventive concept, as required by R. 13.1 PCT.

Point V:

1. The subject-matter of claims 1-5, and 13 is considered to lack inventive step, Art. 33(3) PCT.

1.1 Document D1 (Fig. 1), discloses the following features of independent claim 1:

> A laser vibrometer for identifying remote targets by detecting mechanical vibrations therein (p. 1, par. 1-2), the vibrometer having an array of coherent optical receivers for collecting a portion of laser light reflected by a remote target (6; p. 3, last par. - p. 4, 1st par.), (each receiver providing a signal representative of the remote target).

Thus, the apparatus of claim 1 differs from the disclosure of document D1 in that

> each receiver provides a **coherent** output, and the vibrometer further comprises **signal processor means for combining** said coherent outputs of the receivers to produce a signal representative of the remote target and for removing laser speckle.

These differing features lead to an improved vibrometer precision by means of reduced received noise. Therefore, the objective technical problem to be solved by these distinguishing feature is **to further increase the vibrometer precision by means of reducing the received noise.**

It is well-known in the field of laser vibrometry that laser speckle acts as a significant noise source. Therefore, the skilled person faced with the above stated problem would also search for this aspect and would turn to document D2 which

relates to a laser vibrometer for detecting weather conditions in the atmosphere. In order to overcome the above problem, D2 (fig. 3) discloses the following measures:

> each receiver (of an array of coherent optical receivers: 89, 91, 92) provides a coherent output (94; col. 7, l. 14-19), and the vibrometer comprises signal processor means for combining (94, 96, 100 and phase-locked loop described in col. 4, l. 59-63) the coherent outputs of the receivers to produce a signal (102a) representative of the remote target and for removing laser speckle (col. 7, l. 24-47 and col. 8, l. 18-23).

The above signal processing steps can directly be applied to outputs of amplifiers 15 (fig. 1) of devise disclosed in D1 (**first embodiment**) in order to obtain a speckle minimised signal representative of the target. Hence, the person skilled in the art would readily include without any inventive activity the features disclosed in documents D2 in the device described in document D1 and thus arrives at the subject-matter of claim 1.

1.2 Document D2 discloses the additional feature of dependent claim 2, as follows:

> the signal processor comprise a phase-locked loop (col. 4, l. 59 - col. 5, l. 1) having multiple inputs (89), in which the signal derived from the multiple inputs (102a) is representative of the remote target (col. 5, l. 1-7), substantially unaffected by laser speckle (col. 6, l. 17-23).

1.3 Document D2 discloses the feature of dependent claim 3:

> the phased -locked loop comprises the multiple signal multipliers (89), said multipliers multiplying the input signals (84) by a further signal (90).

The following remaining feature of claim is considered as an usual design measure:

> the further signal is generated by voltage controlled oscillator.

Detecting the frequency by means of a phase-locked loop (PLL) is commonplace

in the field of signal processing, whereas a conventional PLL includes a voltage controlled oscillator (VCO). In the method of D2 the loop is closed at the optical element level (89, col. 5, l. 1-7), therefore in this case "the further signal" is an optical signal (90). D1 in contrast discloses a PLL in the electrical part of the receiver (p. 2, 2nd par., l. 9-14). The skilled person is aware of the fact that such a PLL comprises a VCO providing one of the multipliers input signals ("the further signal").

1.4 The following additional features of dependent claims 4 and 5 merely specify minor implementation details of usual design:

claim 4: the further signal comprises a sinusoidal or a square wave;

claim 5: the phase-locked loop further comprises multiple low pass filters, said filters having cut-off frequencies in the kilohertz region.

1.5 Since claim 13 defines the corresponding method of claim 1, it equally lacks inventive step.

2. In view to the available prior art cited in the International Search Report it appears that the subject-matter of claims 6-12 (the objection to lack of clarity to claims 6 and 12 notwithstanding, see section 3.1, below) is new and involves an inventive step in the sense of Art. 33(3) PCT.

2.1 The combination of the features of dependent claim 6 (invention group 1) (the objection to lack of clarity notwithstanding) is neither known from, nor rendered obvious by, the available prior art. In particular, claim 6 defines the following additional feature:

the phased -locked loop further comprises a summing amplifier which sums the signals generated by the multiple lowpass filters and outputs a signal to an integrator.

Summing the output signals of the lowpass filters includes the amplitude information of the received signals in the combined signal representative for the target. The incorporation of signal amplitudes into the combining process and

thereby weighting the contribution of the signal phases is one of the essential features of the invention, which is neither disclosed nor hinted at in D2. The method of D2 obtains the combined output signal representative for remote target by means of **averaging the phase rates** of receiver signals, thus without considering the signal amplitudes.

2.2 Since dependent claim 7 refer to claim 6, it equally fulfils the requirement of involving an inventive step, Art. 33(3) PCT.

2.3 The following additional feature of dependent claim 8 (invention group 2) is neither known from, nor rendered obvious by, the available prior art:

> the signal processors comprise an autocovariance processor having multiple inputs, in which the signal derived from the multiple inputs is representative of the remote target, substantially unaffected by laser speckle.

The incorporation of an autocovariance processor in the combining process of the receiver signals is not disclosed in any of the cited documents. Moreover, the concept of applying autocovariance signals in speckle reduction leads to an approach completely different from the method disclosed in D2.

2.4 Since dependent claims 9-12 refer to claim 8, they equally fulfil the requirement of involving an inventive step, Art. 33(3) PCT.

3. Further remarks:

3.1 Claims 3, 6, and 12 are considered to lack clarity, Art. 6 PCT.

3.1.1 Dependent claim 3 defines the following additional feature:

> the phase-locked loop comprises multiple signal multipliers, said multipliers **multiplying the input signals** by a further signal generated by a voltage controlled oscillator.

However, it is not apparent from the claim definition, where the input signals are originating from, whereby the claim definition is rendered unclear. Due to the description (p. 5, l. 25 - p. 6, l. 2), each input signal of the phased-locked loop is

provided by a corresponding receiver output, which is considered to be essential to the definition of the invention.

3.1.2 Dependent claim 6 defines the following additional feature:

> the phase-locked loop further comprises a summing amplifier which sums the **signals generated by the multiple low pass filters** and outputs a signal to an integrator.

However, it is not apparent from the claim definition, where the input signals of the low pass filters are originating from. Accordingly, it is unclear which signals are generated by low pass filters, which leads to unclarity of the claim definition.

Additionally, since claim 5 is the single claim which defines "low pass filters", claim 6 should refer to this claim.

3.1.3 Dependent claim 12 contains the following passage::

> "... **said summation causing** the signal due to the laser speckle to be greatly reduced and **a signal representative of** the mechanical vibration of **the remote target to be output by the summation means.**"

However, according to claim 8 the signal representative of the remote target is **derived from the multiple inputs of the autocovariance processor.** Since, claims 8-10 does not define a link between the autocovariance processor and any of in claims 9-10 defined components (including the summation means), above definition renders the subject-matter of claim 12 ambiguous and unclear.

Claim 12 further contains the following passage:

> "...performing a summation on said pairs of signals, **said summation causing** the signal due to the laser speckle to be greatly reduced ..."

The above feature lacks support by the description. According to the description the **summation on autocovariance of the pairs of converted signals** leads to reduced laser speckle and not the mere summation of the pairs of unprocessed converted signals themselves (p.9, l. 3 - p. 10, l. 15).

3.2 Document D2 is not acknowledged in the description, R. 5.1(a)(ii) PCT.

3.3 The present application does not meet the requirements of Rule 6.3(b) PCT that the independent claims should be set out in the two-part form, with those features which in combination are part of the prior art being placed in the preamble.

corresponding to the vibrations of the target. However, the speckle fluctuations at each receiver are substantially uncorrelated with the others, so the signal amplitudes from each receiver pass through minima at different times, so combining the demodulated outputs from each receiver with the others produces a composite signal in which temporary loss of vibrational data from the target is minimised or eliminated.

However, in the method and apparatus described, it is not a straightforward matter to define the optimum method for combining the demodulated outputs from the receiver array to maintain a constant vibration signal, and to minimise the overall receiver noise. For example, a simple addition of the demodulated signals does not give the optimum result.

According to the invention there is provided, a laser vibrometer for identifying remote targets by detecting mechanical vibrations therein, said vibrometer having an array of coherent optical receivers for collecting a portion of laser light reflected by a remote target, each receiver providing a coherent output and signal processor means for combining said coherent outputs of the receivers to produce a signal representative of the remote target and for removing laser speckle.

Optionally, the signal processors may comprise a phase-locked loop having multiple inputs, in which the signal derived from the multiple inputs is representative of the remote target, substantially unaffected by laser speckle. Preferably, the phase-locked loop may comprise multiple signal multipliers, said multipliers multiplying the input signals by a further signal generated by a voltage controlled oscillator. Conveniently, the further signal may comprise a sinusoidal or a square wave. Advantageously, the phase-locked loop may further comprise multiple low pass filters, said filters having cut-off frequencies in the kilohertz region. Preferably, the phase-locked loop further may comprise a summing amplifier which sums the signals generated by the multiple low pass filters and outputs a signal to an integrator and, optionally, the integrator may output a signal to an input of the voltage control oscillator, said voltage control oscillator generating a signal which is input into the inputs of the multiple signal multipliers.

Preferably, the signal processors may comprise an autocovariance processor having multiple inputs, in which the signal derived from the multiple inputs is representative of the remote target, substantially unaffected by laser speckle. Advantageously, the signals output by the multiple receivers may be passed to conversion means, said conversion means sampling the input signals to produce digital outputs in response to timing signals generated by a timing pulse generator. Conveniently, the signals output by the multiple receivers may be further passed to time delay means, said time delay means delaying the input signals by approximately 0.25 of a cycle at the centre frequency of the signals from the receivers. Optionally, the time-delayed signals may be passed to further conversion means, said further conversion means sampling the input signals to produce digital outputs in response to timing signals generated by a timing pulse generator. Preferably, the laser vibrometer may further comprise summation means, for receiving the first and second converted signals, said converted signals comprising signal pairs, and performing a summation on said pairs of signals, said summation causing the signal due to the laser speckle to be greatly reduced and a signal representative of the mechanical vibration of the remote target to be output by the summation means.

According to the invention there is further provided, a method of detecting the mechanical vibrations of a remote target using a laser vibrometer, comprising the steps of:

(a) illuminating the remote target with laser light;

(b) collecting a portion of the laser light reflected by the remote target by means of an array of coherent optical receivers, each receiver providing a coherent output;

(c) processing said coherent outputs by combining together said coherent outputs in order to generate a signal representative of the mechanical vibration of the remote target that is substantially unaffected by laser speckle.

In this way, signals from each receiver are combined, either by means of a phased-locked loop with multiple inputs, for example, or by means of a complex autocovariance processor with multiple inputs, as a further example, to

CLAIMS

1. A laser vibrometer for identifying remote targets by detecting mechanical vibrations therein, said vibrometer having an array of coherent optical receivers for collecting a portion of laser light reflected by a remote target, each receiver providing a coherent output, and signal processor means for combining said coherent outputs of the receivers to produce a signal representative of the remote target and for removing laser speckle.

2. A laser vibrometer according to claim 1, in which the signal processors comprise a phase-locked loop having multiple inputs, in which the signal derived from the multiple inputs is representative of the remote target, substantially unaffected by laser speckle.

3. A laser vibrometer according to claim 2, in which the phase-locked loop comprises multiple signal multipliers, said multipliers multiplying the input signals by a further signal generated by a voltage controlled oscillator.

4. A laser vibrometer according to claim 3, in which the further signal comprises a sinusoidal or a square wave.

5. A laser vibrometer according to any one of claims 2 to 4, in which the phase-locked loop further comprises multiple low pass filters, said filters having cut-off frequencies in the kilohertz region.

6. A laser vibrometer according to any one of claims 2 to 5, in which the phase-locked loop further comprises a summing amplifier which sums the signals generated by the multiple low pass filters and outputs a signal to an integrator.

7. A laser vibrometer according to claim 6, in which the integrator outputs a signal to an input of the voltage control oscillator, said voltage control oscillator generating a signal which is input into the inputs of the multiple signal multipliers.

8. A laser vibrometer according to claim 1, in which the signal processors comprise an autocovariance processor having multiple inputs, in which the signal derived from the multiple inputs is representative of the remote target, substantially unaffected by laser speckle.

9. A laser vibrometer according to claim 8, in which the signals output by the multiple receivers are passed to conversion means, said conversion means sampling the input signals to produce digital outputs in response to timing signals generated by a timing pulse generator.

10. A laser vibrometer according to claim 9, in which the signals output by the multiple receivers are further passed to time delay means, said time delay means delaying the input signals by approximately 0.25 of a cycle at the centre frequency of the signals.

11. A laser vibrometer according to claim 10, in which the time-delayed signals are passed to further conversion means, said further conversion means sampling the input signals to produce digital outputs in response to timing signals generated by a timing pulse generator.

12. A laser vibrometer according to claim 11, further comprising summation means, for receiving the first and second converted signals, said converted signals comprising signal pairs, and performing a summation on said

pairs of signals, said summation causing the signal due to the laser speckle to be greatly reduced and a signal representative of the mechanical vibration of the remote target to be output by the summation means.

13. A method of detecting the mechanical vibrations of a remote target using a laser vibrometer, comprising the steps of:

(a) illuminating the remote target with laser light;

(b) collecting a portion of the laser light reflected by the remote target by means of an array of coherent optical receivers, each receiver providing a coherent output;

(c) processing said coherent outputs by combining together said coherent outputs in order to generate a signal representative of the mechanical vibration of the remote target that is substantially unaffected by laser speckle.